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(54) **Current reducing device**

(57) A device for reducing the amplitude in a conductor (10) of an alternating current at a set frequency and phase has a current sensor (11) feeding an amplifier (12). The output of the amplifier (12) drives a current injector (13) to inject an opposing current of opposite phase to the sensed current to reduce it. The system may be tuned to the set frequency. In a cable tracing arrangement, the opposing current may be derived directly from the signal generator injecting the tracing current in the cable to be traced. Unwanted tracing currents in cables can thus be blocked

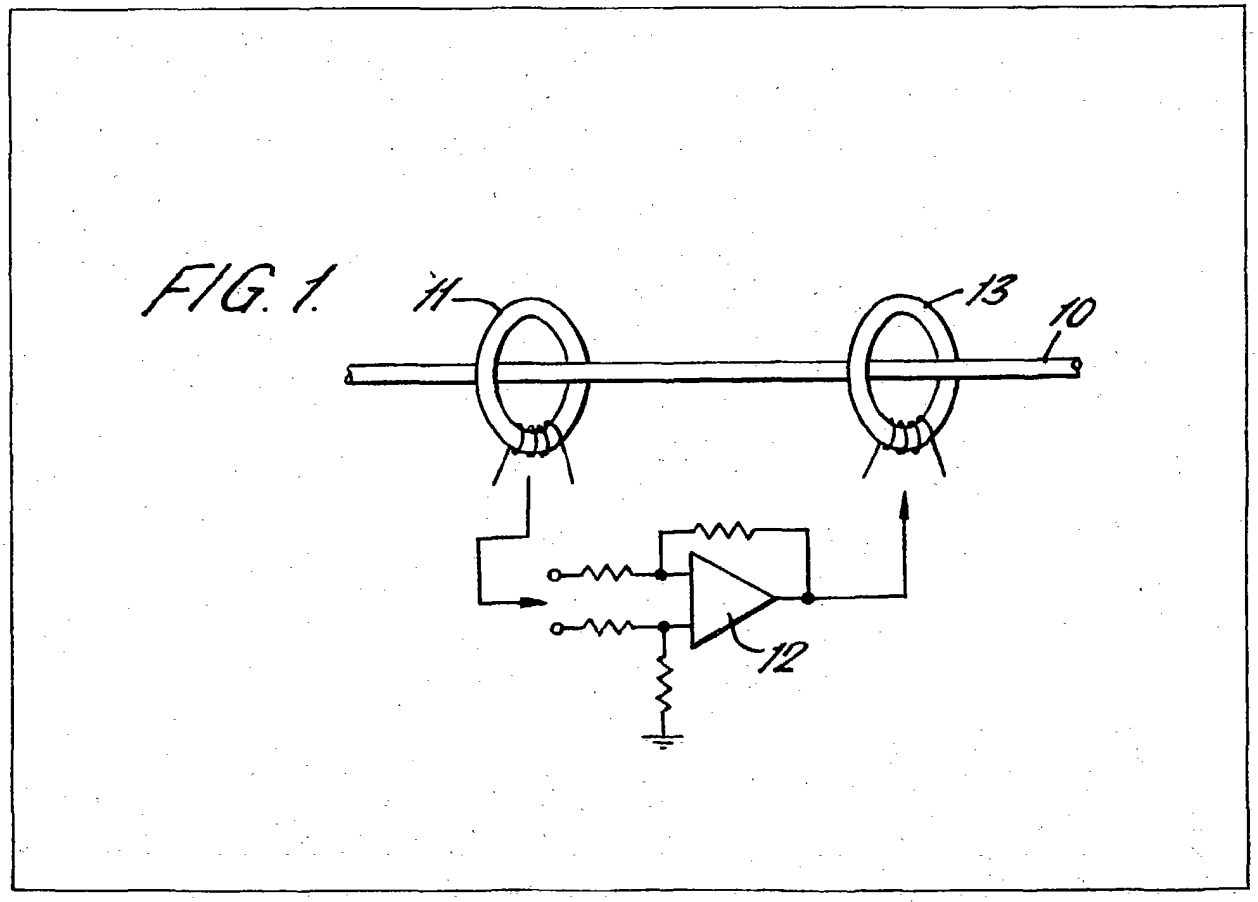

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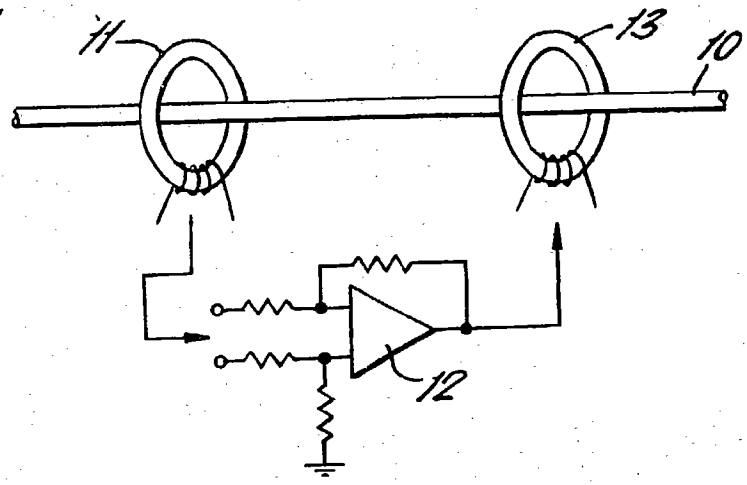
FIG. 1.



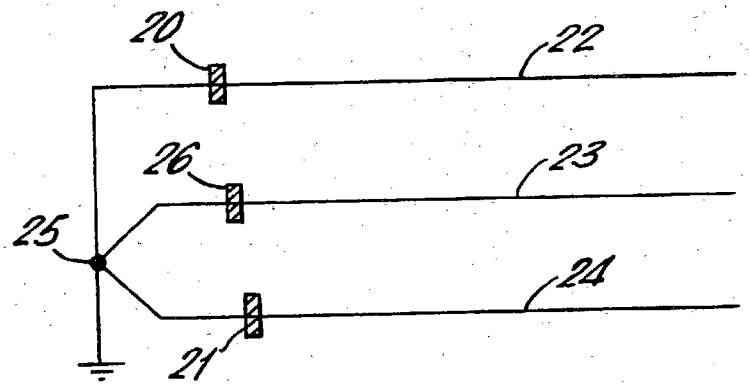
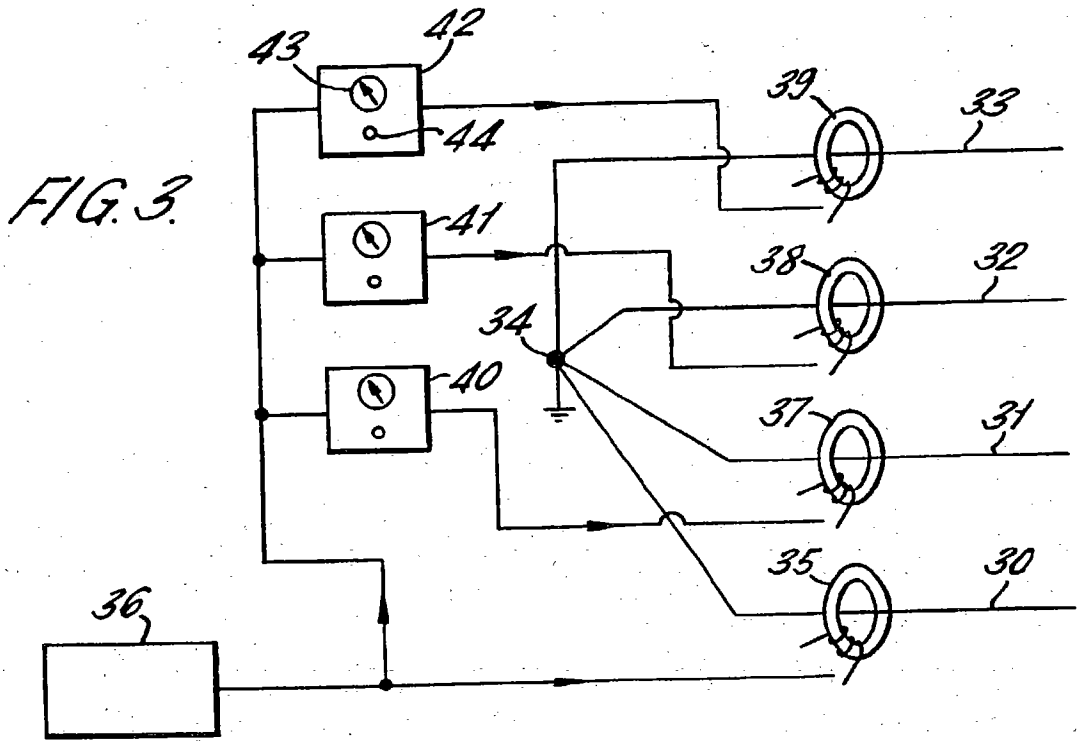


FIG. 2.

FIG. 3.



SPECIFICATION

Current reducing device

The present invention is concerned with a current reducing device and particularly a device for reducing the amplitude of an alternating current in a conductor. There may be various occasions on which it is desirable to reduce an alternating current flowing in a conductor, but the particular problem which the present invention has been designed to alleviate arises in the field of locating underground electric conductors, such as electricity supply cables or metal pipes. Considering supply cables, these have been located by inducing an alternating current signal into the sheath of the cable to be traced and detecting the magnetic field generated by this signal current with a suitable detector or locating instrument above the ground. A problem arises when there is a requirement to trace a single cable amongst other cables which also start from the same sub-station. It has frequently been found that if the signal current is induced in the cable to be traced, the current appears to find its way also into the other cables from the sub-station, so that it is difficult to know which of the various cables from the sub-station the location apparatus is following.

The current reducing device of the present invention can be used to reduce such signal currents flowing in the unwanted cables so that the cable location apparatus responds only to the signal current in the desired cable. A preferred form of the current reducing device can substantially block alternating currents flowing in a conductor.

According to the present invention, there is provided a current reducing device for reducing the amplitude in a conductor of an alternating current of predetermined frequency and phase, the device comprising means for sensing the amplitude of the alternating current in the conductor, and means for injecting into the conductor an alternating current at the predetermined frequency but of opposite phase to said predetermined phase so as to reduce the sensed current amplitude.

In one embodiment, said injecting means is responsive to the sensed current amplitude to inject a current which is proportional in amplitude to said sensed current.

Since the injected current is anti-phase to the sensed current in the conductor, it can be seen that the sensed current amplitude i is equal to an orginal current amplitude I minus the injected current amplitude, the original current amplitude being the amplitude of the alternating current flowing in the conductor in the absence of the current reducing device. If the constant of proportionality (or gain) of the injected current amplitude relative to the sensed current amplitude is α, i.e. the injected current is equal to α i, then $i = I - \alpha i$

$$\therefore i = \frac{I}{1+\alpha}$$

It can be seen therefore that this embodiment of the reducing device operates to reduce the current amplitude in the conductor for all positive values of alpha. Preferably, however, the constant of proportionality or gain (alpha) is greater than unity, so that the alternating current in the conductor is reduced by at least a half. Preferably, the gain is eight or greater, so that the reducing device operates substantially to block the alternating current in the conductor.

Conveniently, the means for sensing comprises a current transformer. Current transformers are well known for sensing and measuring currents flowing in long conductors. Typically they comprise a toroidal coil wound on a laminated core in the form of a ring, which can be clipped around the conductor in which the current is to be sensed.

In one convenient arrangement of this embodiment, said means for injecting comprise an amplifier connected to produce an output voltage representative of the sensed current, and a current injector connected to be driven by the amplifier voltage. Again, the current injector may comprise a current transformer. It is known to use current transformers for injecting current into long conductors. The injecting transformer may be similar to or even identical to the sensing transformer.

In another embodiment, said means for sensing includes an indicator for providing an indication of the amplitude of the sensed current and said means for injecting includes a control means for adjusting the amplitude of the injected current to minimise the indicated amplitude of the sensed current. When the alternating current to be reduced is stray current in one of a set of conductors which are interconnected at an earth point from a signal generator which is for impressing a desired alternating current in another conductor of the set, the output from the signal generator may be fed to said means for injecting to control the phase of the injected current This arrangement ensures that the injected signal is accurately synchronised with and anti-phase to the stray signal currents to be reduced. The device ignores any noise currents in the conductor at the predetermined frequency which can saturate the amplifier of the above first described embodiment.

The invention also envisages a method of tracing one of a plurality of underground electrical conductors emanating from a common earthing point, comprising inducing an alternating current sensing signal into the conductor to be traced, reducing any component of said sensing signal current flowing in each of the conductors other than the one to be traced using a current reducing device as claimed in any preceding claim, and then tracing the conductor with a location instrument responsive to the magnetic field generated by the signal current.

Examples of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a schematic representation of a current reducing device embodying the present invention;

Figure 2 is a further schematic representation illustrating a possible application of the device of Figure 1; and

Figure 3 is a schematic representation of a different embodiment of the present invention.

Referring to Figure 1, a current reducing device is

illustrated in position for reducing alternating current flowing in a cable 10. The current reducing device comprises a current sensor 11 which may typically comprise a toroidal coil wound on an annular laminated former which encircles the cable 10. Current transformers of this form are well known and a standard current transformer may be suitable as the current sensor 11. Normally, the coil of the sensor 11 will be in two parts so that the coil can be clipped around the cable 10. The current sensor 11 produces an alternating voltage across the coil having an amplitude proportional to the amplitude of the current flowing in the cable 10. This output voltage from the sensor 11 is fed to the input of an amplifier 12 and the output signal from the amplifier 12 is then fed in turn to a current injector 13. The current injector 13 may also comprise a toroidal coil wound on an annular laminated core encircling the cable 10. In a simple arrangement, the current sensor 11 and the injector 13 are identical. The output from the amplifier 12 is applied to the coil of the injector 13 so that the injector induces a current component in the cable 10 corresponding to the output voltage of the amplifier. In order for the device of Figure 1 to be effective in reducing the alternating current flowing in the cable 10, it is arranged so that the current component induced by the injector 13 is of opposite phase to the original current flowing in the cable. This may be achieved either by arranging for the amplifier 12 to invert the amplified voltage and having the coil of the injector 13 wound in the same sense as the coil of the sensor 11, or using an non-inverting amplifier 12 and having the winding of the injector 13 in the opposite sense to that of the sensor 11.

Considering an example in which the current component induced in the cable 10 by the injector 13 is nine times the resultant current flowing in the cable and sensed by the sensor 11, i.e. the device has a gain of 9, then an original current of 1 mA flowing in the cable 10 in the absence of the device, will be reduced by the device to a resultant current of 0.1 mA.

In order to ensure proper operation of the device with the sensor 11 and the injector 13 formed as current transformers, it is important to ensure that there is substantially no flux linkage between the coils of the sensor and injector. Also, it will be appreciated that there is a limit to the current which can be injected into the cable 10 by the injector 13 before the core of the injector saturates. Thus, the device in the form described is only suitable for relatively small currents. Also, operation of the device is very sensitive to resistance in the cable 10. It will be appreciated that the injector 13 in the form described is not capable of generating any substantial e.m.f. in the cable 10 to overcome such a resistance. There is, in effect, only a single turn in the secondary of the transformer formed by the injector 13 with the cable 10. Thus, the e.m.f. which can be induc d into the cable 10 is limited if saturation of the core of the injector 13 is to be avoided and if phase changes are to be kept to a minimum. It will be appreciated that it is important that the current injected by the injector 13 and the original current flowing in the cable 10 be maintained strictly anti-phase. Undesirable phase shift becomes an increasing problem with attempts to increase the "gain" of the device. Instead of the linear amplifier 12, a digital analyser may be employed to analyse the wave form sensed by the sensor 11 to predict and produce automatically using digital techniques, a suitable blocking signal for inducing the required opposing current in the cable.

Referring now to Figure 2, an application is illustrated for a current reducing device such as that of Figure 1. In fact in Figure 2 two such devices are shown at 20 and 21. It is a common requirement to trace or find a cable or other conductor which may be buried, or laid in an underground conduit. For example, it is frequently desirable to trace mains power distribution cables. One well known way of doing this is to induce a small alternating current, at a known frequency, in the metal sheath of the cable to be traced. Then location apparatus can be used above the ground to detect the magnetic field produced by this alternating current. However, it is common practice for several distribution cables to originate from a single sub-station at which the screens or sheaths of the different cables are all earthed. It has been found that even if the alternating current signal is induced in the cable to be traced, the signal tends to flow also in the other cables emanating from the common sub-station. Thus, it can be difficult to know which of the various cables from the sub-station that the cable location instrument above the ground surface is tracking. This problem can be greatly alleviated using current reducing devices embodying the present invention.

Figure 2 shows schematically three mains distribution cables 22, 23 and 24 all having their screens earthed together at 25, for example at a common sub-station. If it is desired to trace a cable 23, an alternating current tracing signal is induced into the screen of the cable by a signal injector 26. The signal injector 26 is commonly applied to the cable 23 at or adjacent to the sub-station. The current reducing devices 20 and 21 are then applied to the other cables emanating from the common sub-station at points near the common earthing point 25 so that any current from the signal injector 26 finding its way to the cables 22 and 24 is substantially reduced. The sensing signal is then substantially restricted to the desired cable 23 which can be traced more easily.

Current producing devices as described above have been found to be effective. However, it is desirable to tune the elements of the device narrowly to the frequency of the tracing signal induced into the cable to be traced. This is desirable to prevent the device reacting to noise currents at other frequencies which could otherwise saturate th amplifier 12. Furthermore, although, in the ideal case, the current injected into the cable by the injector 13 should be 180° out of phase with the sensed current to be reduced, in practice it is desirable to permit some adjustment of the actual phase difference between the sensed and injected currents. Accordingly, in a preferred arrangement of the current reducing device, the amplifier 12 has adjustable controls for setting the tuning of the pass band of the amplifier, the gain of the amplifier, and the phase of the injected current relative to the sensed current. With

such an arrangement, an unwanted tracing signal in a conductor could be reduced by between twenty and thirty decibels.

However, the above described device has been found not to function very well on cables feeding very noisy loads. It has been found that large spurious noise components, even at the tuned frequency of the device, tend to saturate the amplifier.

Figure 3 illustrates a different embodiment of current blocking device which can deal with cables feeding noisy loads. In Figure 3, a set of four cables 30 to 33 are shown with their outer sheaths connected together at an earthing point 34. Such an earthing point may typically be in distribution substation where the cables are mains distribution cables.

In the present example cable 31 is to be traced and an alternating current tracing signal is induced into cable 30 by means of a current transformer 35 driven by a signal generator 36. Spurious tracing currents appearing in cables 31, 32 and 33 are reduced by means of respective current transformer 37, 38 and 39 driven by controllers 40, 41 and 42. The controllers 40 to 42 are fed with the output signal of the signal generator 36 so that the current injected by the controllers 40 to 42 via the current transformers 37 to 39 can be accurately synchronised with and anti-phase to the stray tracing current appearing in cables 31, 32 and 33 as a result of the current injected into the cable 30. Accordingly, the controllers 40 and 42 may comprise simply current amplifiers arranged to drive currents in the transformers 37 to 39 corresponding to the output signal of the signal generator 36 but anti-phased with the stray tracing currents in the cables 31 to 33. Each controller 40 to 42 includes an indicator 43 and a gain control knob 44. The indicator 43 is arranged to provide an indication of the net current at the frequency of the signal generator 36 in the respective cable 31 to 33. In operation, the gain control knob 44 is set to minimise this current so that the current injected by the current transformers 37 to 39 accurately negates the stray tracing current appearing in the respective cable.

It can be seen that using this technique the problem of saturation of the current producing device as a result of high noise levels in the cable is avoided since only a signal at the same frequency as the tracing signal is injected.

In the arrangement shown in Figure 3, a single current transformer 37 to 39 to used with each of the controllers 40 to 43. It will be appreciated that the voltage across the current transformers 37 to 39 at any time are representative of the current flowing in the cables 31 to 33, assuming that the current transformers have negligible resistance. Accordingly, the meters 43 of the controllers can be arranged to monitor the voltage drop across the current transformers. The output signals from the controllers 40 to 42 drive current in the current transformers to negate the stray tracing signals and effectively minimise the signal voltage appearing across the transformers.

Preferably, however, separate current transformers are employed with each controller 40 to 42, one for sensing the current in each cable at the tracing signal frequency and another for injecting an opposing current. Otherwise, the operation is the same as for single current transformers.

Instead of providing manual control as described, each controller 40 to 42 may have automatic gain control arranged to control the gain of the current output to the injecting current transformers so as to minimise automatically the current at the signal frequency in the respective cable.

The embodiment of the invention illustrated in Figure 3 has been found to work well on relatively noisy cables.

CLAIMS

1. A current reducing device for reducing the amplitude in a conductor of an alternating current of predetermined frequency and phase, the device comprising means for sensing the amplitude of the alternating in the conductor, and means for injecting into the conductor an alternating current at the predetermined frequency but of opposite phase to said predetermined phase so as to reduce the sensed current amplitude.

2. A device as claimed in claim 1, wherein the means for sensing comprises a current transformer.

3. A device as claimed in claim 1 or claim 2, wherein said injecting means is responsive to the sensed current amplitude to inject a current which is proportional in amplitude to said sensed current.

4. A device as claimed in claim 3, wherein the constant of proportionality of gain between the amplitudes of the injected and sensed currents is greater than unity.

5. A device as claimed in claim 4, wherein the gain is eight or greater.

6. A device as claimed in any of preceding claims 3 to 5, wherein said means for injecting comprises an amplifier connected to produce an output voltage representative of the sensed current, and a current injector connected to be driven by the amplifier output voltage.

7. A device as claimed in claim 6, wherein the current injector comprises a current transformer.

8. A device as claimed in claim 1 or claim 2, wherein said means for sensing includes an indicator for providing an indication of the amplitude of the sensed current and said means for injecting includes a control means for adjusting the amplitude of the injected current to minimise the indicated amplitude of the sensed current.

9. A device as claimed in claim 8, wherein the alternating current to be reduced is stray current in one of a set of conductors which are interconnected at an earth point from a signal generator which is for impressing a desired alternating current in another conductor of the set, and the output from the signal generator is fed to said means for injecting to control the phase of the injected current.

10. A device as claimed in claim 8 or claim 9, wherein said means for injecting includes a current transformer and means for driving current in the transformer, said means for sensing comprising means for sensing the voltage across the transformer.

11. A current reducing device substantially as hereinbefore described with reference to Figures 1 and 2 or Figure 3 of the accompanying drawings.

12. A method of tracing one of a plurality of under ground electrical conductors emanating from a common earthing point, comprising inducing an alternating current sensing signal into the conductor to be traced, reducing any component of said sensing signal current flowing in each of the conductors other than the one to be traced using a current reducing device as claimed in any preceding claim, and then tracing the conductor with a location instrument responsive to the magnetic field generated by the signal current.

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